

# Dual-Hormone Changes Are Related to Bargaining Performance

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## Abstract

In the present research, we found that endogenous testosterone and cortisol changes were jointly related to bargaining outcomes. In a face-to-face competitive negotiation (Study 1) and a laboratory-based bargaining game (Study 2), testosterone rises were associated with high earnings and high relationship quality, but only if cortisol dropped. If cortisol rose, testosterone rises were associated with low earnings and poor relationship quality. Conflict between financial and social goals was related to the financially costly dual-hormone profile (testosterone increase and cortisol decrease), whereas the absence of such conflict was related to the financially adaptive dual-hormone profile (testosterone increase and cortisol increase). The findings suggest that when cortisol decreases, rising testosterone is implicated in adaptive bargaining behavior that maximizes earnings and relationship quality. But when cortisol increases, rising testosterone is related to conflict between social and financial motives, weak earnings, and poor relationship quality. These results imply that there are both bright and dark sides to rising testosterone in economic social interactions that depend on fluctuations in cortisol.

## Keywords

decision making, bargaining, negotiation, testosterone, cortisol

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Bargaining is a mixed-motive interaction in which financial and social goals are at stake (Rilling & Sanfey, 2011; Thompson, Wang, & Gunia, 2010). On the one hand, individuals are motivated to maximize earnings. But on the other hand, this economic motive may conflict with social concerns. For example, a businessman selling a manufacturing plant may be concerned that demanding too high a price will put a strain on his relationship with a potential buyer. Thus, he may sacrifice some earnings because he believes this will ensure a harmonious relationship (Amanatullah, Morris, & Curhan, 2008). Another negotiator may perceive a low take-it-or-leave-it offer as unfair and disrespectful. Even if accepting this offer is in her best financial interest, she may reject the offer because her motivation to retaliate against the perceived insult may outweigh her desire to maximize earnings (Rilling & Sanfey, 2011). These examples illustrate the potent conflict between social and economic goals that some individuals experience in bargaining contexts, yet it remains

unknown what role neuroendocrine systems play in managing this conflict.

Neuroendocrine theories have linked both financial and social concerns to testosterone. In some studies, testosterone measured in the afternoon (Apicella et al., 2008) or morning (Coates & Herbert, 2008) was positively related to behavior that maximizes monetary rewards. But other studies show that testosterone—when measured in the afternoon (Burnham, 2007; Mehta & Beer, 2010) or when exogenously administered (Zak et al., 2009)—predicts heightened social concerns that trump financial ones (e.g., status and reputation concerns; but see Eisenegger, Naef, Snozzi, Heinrichs, & Fehr, 2010, and Zethraeus et al., 2009, for different results). To date,

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it remains unclear when testosterone should stimulate financially adaptive behaviors versus financially costly behaviors driven by social concerns.

One explanation for a lack of consensus on the function of testosterone in bargaining contexts may be that most prior research has measured or manipulated testosterone concentrations *prior* to a bargaining interaction. But it may be that acute testosterone changes *during* a bargaining interaction may play a stronger role in explaining earnings in bargaining contexts. Indeed, state testosterone (testosterone fluctuation in a social interaction) is more strongly related to social behavior than trait testosterone (baseline testosterone) in other research domains, such as in previous studies on aggression (Carré, McCormick, & Hariri, 2011).

Another explanation is that testosterone's association with earnings in bargaining contexts may depend on cortisol, the primary end product of the hypothalamic-pituitary-adrenal axis. Cortisol increases are associated with social evaluative stress and behavioral inhibition, whereas cortisol decreases are associated with relaxation and approach-oriented behavior (Dickerson & Kemeny, 2004; Roelofs et al., 2009). Prior research has focused on testosterone's role in bargaining independent of cortisol. However, cortisol can influence the pathway between testosterone and behavior at multiple levels (testosterone can also influence the pathway between cortisol and behavior; Viau, 2002), and these two hormones interactively predict social behaviors outside of bargaining contexts (Dabbs, Jurkovic, & Frady, 1991; Denson, Mehta, & Ho Tan, 2013; Edwards & Casto, 2013; Mehta & Josephs, 2010; Popma et al., 2007). For instance, higher basal testosterone predicts more-dominant leadership behaviors when basal cortisol is low, but when basal cortisol is high, higher basal testosterone predicts greater threat sensitivity and stress-related leadership behaviors (e.g., nervousness and anxiousness; Mehta & Josephs, 2010). This dual-hormone interaction also predicts social status in collegiate sports teams (Edwards & Casto, 2013).

These studies support a *dual-hormone hypothesis*: High testosterone coupled with low cortisol is an adaptive endocrine profile in status-relevant contexts such as leadership, whereas high testosterone coupled with high cortisol is a maladaptive profile. Some of the same mechanisms that regulate dominant, approach-oriented leadership behaviors may also underlie bargaining behaviors that maximize monetary rewards (e.g., reward processing), and some of the same mechanisms that regulate stress-related leadership behaviors may also underlie financially costly bargaining behaviors driven by social concern (e.g., threat processing; Gospic et al., 2011; Hermans et al., 2010; Johnson, Leedom, & Muhtadie, 2012). Thus, dual-hormone interactions may extend beyond leadership to bargaining behaviors as well.

Although research on the dual-hormone hypothesis has been restricted to the study of basal hormones, emerging evidence for state hormone fluctuations as predictors of human behavior (e.g., Carré et al., 2011) suggests that testosterone and cortisol changes during bargaining may interactively relate to earnings. This hypothesis, however, has yet to be empirically tested.

Building on the dual-hormone hypothesis as well as on research on the interplay between social and financial goals in bargaining situations (Amanatullah et al., 2008; Rilling & Sanfey, 2011; Thompson et al., 2010), we propose that increases and decreases in testosterone and cortisol may be associated with heightened or muted conflict between social and financial motives in bargaining situations (Fig. 1). According to our dual-hormone model, when cortisol levels drop, a testosterone increase should relate to behavior that maximizes financial earnings. But when cortisol levels are elevated, a testosterone increase should be associated with conflict between social and financial concern as well as lower earnings. We tested this dual-hormone model in two studies. In both studies, we placed participants in a bargaining situation and obtained saliva samples to model changes in testosterone and cortisol that occurred during the bargaining process.

## Study 1: Face-to-Face Competitive Negotiations

### Method

**Participants.** Seventy Master of Business Administration students (39% women, 61% men) enrolled in a managerial-negotiations course at Columbia Business School participated in the study on a voluntary basis. The sample size was determined by the overall size of the class and the willingness of students to participate. All procedures were approved by the Columbia University Institutional Review Board. The final analysis included 64 participants with complete hormone data.

**Procedure.** Prior research suggests that some negotiators worry about the negative social consequences of negotiating (Babcock, Gelfand, Small, & Stayn, 2006). These individuals perceive the financial goal of maximizing earnings and the social goal of maintaining a good relationship to be at odds with each other. In the first week of the course, participants completed an online survey outside of class that consisted of a five-item scale that measures chronic concerns about the negative social consequences of negotiating (Babcock et al., 2006). Items on this measure include "If I ask for what I want from someone, it will put stress on our relationship" and "Asking someone for what I want creates harmful conflict" (Cronbach's  $\alpha = .80$ ).

		HPG Axis Activity	
		Testosterone Decrease	Testosterone Increase
HPA Axis Activity	Cortisol Decrease	No Prediction	High Earnings Absence of Conflict Between Social and Financial Concern
	Cortisol Increase	No Prediction	Low Earnings Social Concern That Conflicts With Financial Concern

**Fig. 1.** Predictions of our dual-hormone model, in which changes in testosterone and cortisol are related to the level of earnings in a bargaining situation. HPA = hypothalamic-pituitary-adrenal, HPG = hypothalamic-pituitary-gonadal.

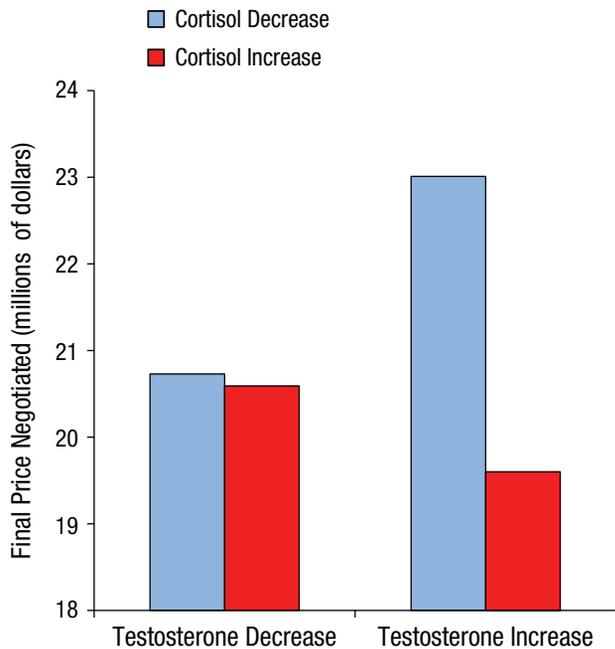
The study was conducted in the second class session (i.e., in the course's second week) before students learned bargaining strategies. Participants were asked to refrain from eating or drinking anything besides water for the 1 hr prior to class. The study began between 10:30 a.m. and 3:30 p.m. (see the Supplemental Material available online for limitations associated with time of day). Participants provided informed consent, followed by a 1.5-mL saliva sample. Standard procedures for collecting salivary hormones were used (Schultheiss & Stanton, 2009).

For the negotiation task, participants were randomly paired with a partner and randomly assigned to the role of buyer or seller. All participants read the instructions for their role. We used a standard distributive negotiation case called Synertech-Dosagen, which focuses on the final price for the sale and purchase of a pharmaceutical plant (Galinsky & Mussweiler, 2001). The seller's role materials indicated that the best alternative to simply selling the pharmaceutical plant was to strip the plant of equipment and then sell the plant and equipment separately; this would be expected to yield earnings of a minimum of \$17 million and take 3 months. The buyer's materials indicated that the best alternative to buying the plant was to build a new plant for \$25 million, which would take 1 year to complete. Negotiators tended to reach agreements on a final price between \$17 and \$25 million ( $M = \$20.8$  million,  $SD = \$3.31$  million). Seller-buyer pairs negotiated for approximately 15 min and then reported the final agreed-on price. Two pairs reached deals outside of the \$17 to \$25 million range (one pair below the range and one pair above it).

Immediately after the negotiation, participants filled out an online survey in which they reported the final

price of the negotiation, their subjective satisfaction with the financial outcome of the negotiation, and their perceived quality of the relationship with their partner. Subjective satisfaction with the financial outcome was rated on a 12-point scale from *extremely dissatisfied* to *extremely satisfied* in response to the question, "How satisfied are you with the final outcome and result of this negotiation?" Perceived quality of the relationship was assessed using six items: "How satisfied are you with the quality of the negotiation interaction itself—the quality of the personal exchange you had with your partner, regardless of outcome?" (rated on a 12-point scale from *extremely dissatisfied* to *extremely satisfied*); "I had respect for my partner" (rated on a 7-point scale from *not at all* to *definitely*); "What level of rapport or comfort did you feel with your partner?" (rated on a 7-point scale from *not much* to *a great deal*); "Now, after the negotiation, do you feel like you could trust your partner in future negotiations?" (rated on a 7-point scale from *strongly disagree* to *strongly agree*); "Do you feel that your partner is a good, likeable person?" (rated on a 7-point scale from *strongly disagree* to *strongly agree*); and "Do you look forward to future interactions and teamwork with your partner?" (rated on a 7-point scale from *strongly disagree* to *strongly agree*).

We standardized individual item scores by converting them to  $z$  scores and then averaging across buyer and seller standardized scores to create a dyadic measure of relationship quality (Cronbach's  $\alpha = .84$ ). High scores indicated mutual trust, liking, respect, and a desire to work together in the future. Our primary research questions focused on associations between dual-hormone changes and earnings (final settlement price), but hormone changes



**Fig. 2.** Final price negotiated as a function of whether sellers' testosterone and cortisol increased (1 *SD* above the mean) or decreased (1 *SD* below the mean) in Study 1.

may also have implications for the quality of the social relationship among negotiators. Hence, follow-up analyses were conducted to examine associations between hormone changes and relationship quality.

After completing the questionnaire and approximately 20 min after the end of the negotiation, participants provided a second saliva sample. This delay was chosen because prior studies demonstrate that cortisol changes peak approximately 20 min after a social evaluative stressor, and a similar time course has been shown for testosterone changes (e.g., Denson, Mehta, & Ho Tan, 2013; Dickerson & Kemeny, 2004; see the Supplemental Material for additional discussion on the saliva-sampling strategy). The saliva samples were shipped on dry ice to Yerkes Biomarkers Core Laboratory (Emory University, Atlanta, GA) and were analyzed for testosterone and cortisol concentrations in duplicate (Diagnostic Systems Laboratories, Webster, TX). Average intra-assay coefficient of variation was less than 15% for testosterone and cortisol, and interassay coefficients of variation averaged across high and low controls were 13.05% for testosterone and 10.41% for cortisol. Prenegotiation testosterone and cortisol levels were in the normal ranges (testosterone in men:  $M = 81.6$  pg/mL,  $SD = 44.1$ ; testosterone in women:  $M = 14.3$  pg/mL,  $SD = 10.7$ ; cortisol in men:  $M = 0.61$   $\mu$ g/dL,  $SD = 0.82$ ; cortisol in women:  $M = 0.50$   $\mu$ g/dL,  $SD = 0.33$ ). Mean hormone changes were close to zero, with substantial variance around the means (see the Supplemental Material).

## Results

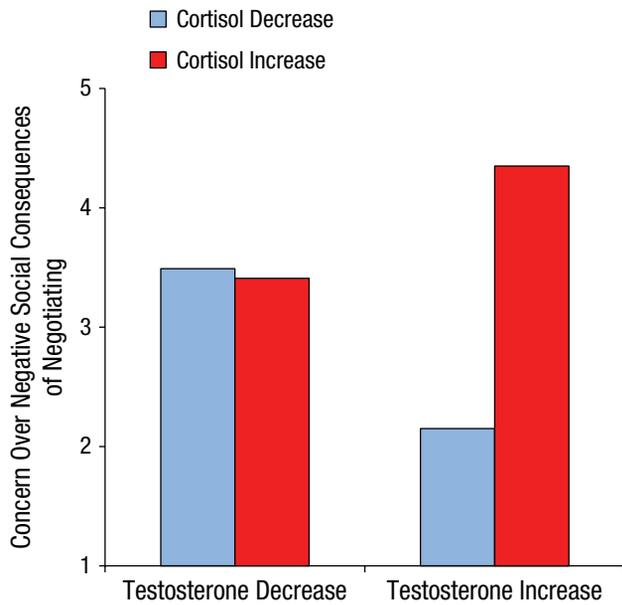
### *Dual-hormone profiles and financial earnings.*

Our dual-hormone model posits that the interaction between testosterone and cortisol changes should be related to economic profit. Specifically, we expected that a rise in testosterone during the negotiation would be associated with higher overall earnings if cortisol simultaneously dropped, but a rise in testosterone would be associated with lower earnings if cortisol increased.

To test this hypothesis, we conducted hierarchical multiple regression analyses in which we regressed the final price of the negotiation onto seller and buyer hormone-change variables. In Model 1, sellers' percentage changes in testosterone and cortisol (standardized) were entered in Step 1, and the seller Testosterone Change  $\times$  Cortisol Change interaction was added in Step 2. In Model 2, buyers' percentage changes in testosterone and cortisol (standardized) were entered in Step 1, and the buyer Testosterone Change  $\times$  Cortisol Change interaction was added in Step 2. In agreement with our dual-hormone model, there was a statistically significant Testosterone Change  $\times$  Cortisol Change interaction for sellers ( $\Delta R^2 = .16$ ;  $b = -1.06$ , 95% confidence interval, or CI =  $[-1.94, -0.17]$ ),  $t(29) = -2.44$ ,  $p = .021$ . There were nonsignificant effects for changes in testosterone and cortisol and the Testosterone Change  $\times$  Cortisol Change interaction for buyers ( $ps > .60$ ), which indicates that the dual-hormone interaction was specific to sellers. Two pairs of negotiators reached deals outside of the \$17 to \$25 million range, but a Testosterone Change  $\times$  Cortisol Change interaction still emerged for sellers when these participants were excluded ( $\Delta R^2 = .13$ ;  $b = -0.74$ , 95% CI =  $[-1.47, -0.012]$ ,  $p = .047$ ). This latter analysis was used to interpret the interaction because we deemed it a more conservative test of our dual-hormone hypothesis. We graphed the final price scores one standard deviation above and below the means for testosterone and cortisol changes and conducted simple slopes tests (Aiken & West, 1991).

In agreement with our dual-hormone model, results showed that sellers whose testosterone increased and cortisol decreased had stronger overall earnings in the negotiation (i.e., final price was higher), whereas sellers whose testosterone and cortisol both increased had weaker overall earnings (final price was lower; Fig. 2). Simple slopes analyses confirmed this interpretation. Cortisol change and the final price negotiated were negatively related when testosterone increased ( $b = -1.51$ , 95% CI =  $[-2.883, -0.134]$ ),  $t(28) = -2.25$ ,  $p = .033$ , but were unrelated when testosterone decreased ( $b = -0.04$ , 95% CI =  $[-0.746, 0.657]$ ),  $t(28) = -0.13$ ,  $p = .897$  (see Fig. 2).

This seller-specific effect was not predicted but is consistent with past research showing that negotiation outcomes are affected more by characteristics of the person



**Fig. 3.** Self-reported concern over the negative social consequences of negotiation as a function of whether sellers' testosterone and cortisol increased (1 *SD* above the mean) or decreased (1 *SD* below the mean) in Study 1.

in the seller role than by characteristics of the person in the buyer role (Amanatullah et al., 2008). Although the reasons for seller-specific effects in the current study remain unclear, some researchers have argued that the high-power nature of the role may be involved (Amanatullah et al., 2008). Other research suggests that the seller role is associated with an approach-oriented goal of maximizing financial gains (Appelt, Zou, Arora, & Higgins, 2009). Thus, it is plausible that a testosterone increase combined with a cortisol decrease predicts strong financial earnings in sellers via motives intended to maximize power or monetary rewards, a hypothesis that warrants further research.

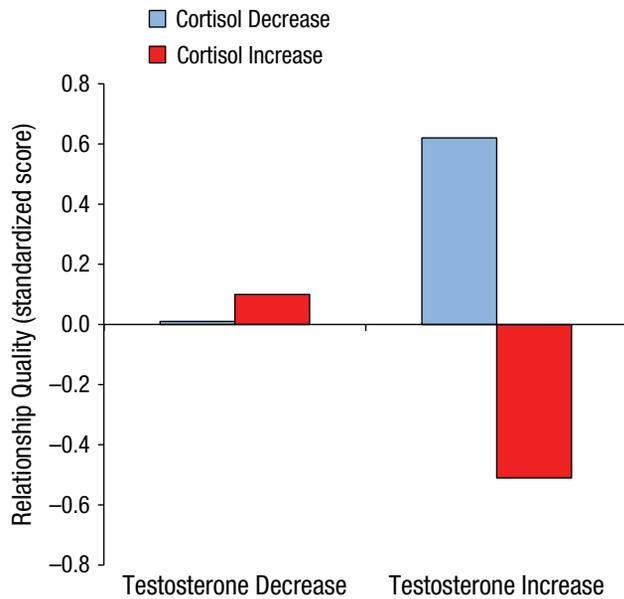
**Dual-hormone profiles and social concern.** We next tested the hypothesis that social concern that conflicts with financial concern would be related to the financially costly dual-hormone profile that we found in sellers (increases in both testosterone and cortisol). To investigate the possibility of a social-concern mechanism, we conducted a hierarchical regression analysis in which trait social concern was the outcome variable. Changes in testosterone and cortisol for sellers were entered in Step 1, and the Testosterone Change  $\times$  Cortisol Change interaction was added in Step 2. This analysis revealed a Testosterone Change  $\times$  Cortisol Change interaction ( $\Delta R^2 = .20$ ;  $b = 0.52$ , 95% CI = [0.128, 0.909]),  $t(29) = 2.72$ ,  $p = .011$  (Fig. 3). High concern over the negative social consequences of negotiation was associated with the financially costly hormone profile (increases in both testosterone

and cortisol), whereas low social concern was associated with the financially beneficial hormone profile (an increase in testosterone and a decrease in cortisol). Simple slopes analyses confirmed this interpretation. Cortisol change and trait social concern were positively related when testosterone increased ( $b = 1.00$ , 95% CI = [0.247, 1.749]),  $t(29) = 2.72$ ,  $p = .011$ , but were unrelated when testosterone decreased ( $b = -0.04$ , 95% CI = [-0.419, 0.341]),  $t(29) = -0.21$ ,  $p = .835$ .

**Mediation analyses.** The results for sellers provide initial empirical support for the theoretical model presented in Figure 1. Further, the results suggest that the relationship between trait social concern and financial earnings may be mediated by the Testosterone Change  $\times$  Cortisol Change interaction. Thus, a mediation analysis was conducted using bootstrapping with trait social concern of sellers as the independent variable, testosterone change and cortisol change for sellers as covariates, the Testosterone Change  $\times$  Cortisol Change interaction for sellers as the proposed mediator, and the final settlement price as the dependent variable (Preacher & Hayes, 2008). This analysis revealed a statistically significant indirect effect ( $M = -0.38$ ,  $SE = 0.24$ , 95% CI = [-1.13, -0.06]). These analyses provide preliminary evidence for statistical mediation consistent with a pathway from trait social concern to dual-hormone changes to earnings.

**Follow-up analyses.** Our primary research questions focused on financial earnings, but dual-hormone changes may also have implications for relationship quality in bargaining contexts. One possibility is that the financially costly dual-hormone profile (increases in both testosterone and cortisol) may relate to high relationship quality in negotiations. After all, concern over the negative social consequences of negotiating was related to this hormone profile, which suggests that individuals in whom testosterone and cortisol both rose may have behaved in ways that ensured a harmonious relationship with their partners. But a second possibility is that the conflict these individuals perceived between managing the relationship and earning money—which was linked to elevated testosterone and cortisol—may ironically have related not only to poor earnings but also to poor rapport with their negotiation partners. This possibility is consistent with research on psychosocial threat in negotiations, which shows that individuals who experience conflict between social and financial goals may fail to achieve either goal (O'Connor, Arnold, & Maurizio, 2010).

Using the same two models as in our examination of the role of dual-hormone changes in predicting the final settlement price of the negotiation, we conducted hierarchical regression analyses to determine whether buyers' or sellers' hormone changes were related to relationship



**Fig. 4.** Relationship quality in the negotiation task (standardized scores) as a function of whether sellers' testosterone and cortisol increased (1 *SD* above the mean) or decreased (1 *SD* below the mean) in Study 1. Higher scores indicate greater mutual liking, respect, and desire to work together in the future.

quality. These analyses revealed only a Testosterone Change  $\times$  Cortisol Change interaction for sellers on relationship quality ( $\Delta R^2 = .19$ ;  $b = -0.28$ , 95% CI =  $[-0.493, -0.058]$ ),  $t(29) = -2.60$ ,  $p = .015$ . As shown in Figure 4, sellers whose testosterone rose while their cortisol dropped had better relationship quality compared with sellers whose testosterone and cortisol both rose. Simple slopes analyses confirmed this interpretation. Cortisol change and relationship quality were negatively related when testosterone increased ( $b = -0.51$ , 95% CI =  $[-0.931, -0.0943]$ ),  $t(29) = -2.51$ ,  $p = .018$ , but were unrelated when testosterone decreased ( $b = 0.04$ , 95% CI =  $[-0.173, 0.250]$ ),  $t(29) = 0.37$ ,  $p = .711$ . These analyses indicate that the profile of increased testosterone combined with decreased cortisol was associated not only with advantageous financial outcomes (earnings) but also with advantageous social outcomes (relationship quality).

**Supplementary analyses.** Supplementary analyses revealed that (a) dual-hormone interaction effects were corroborated when using alternative approaches for analyzing hormone-change scores and when including relevant control variables in statistical models (e.g., time of day to control for diurnal rhythms in hormone concentrations), (b) gender did not moderate dual-hormone interaction effects, and (c) basal hormones were not significantly related to any of the dependent measures (see the Supplemental Material).

## Study 2: Bargaining in the Ultimatum Game

The results of Study 1 indicate that the degree to which individuals experience tension between financial and social motives relates to financially beneficial and costly dual-hormone profiles. However, a direct test of our proposed model requires a controlled bargaining paradigm that explicitly pits financial and social concerns against each other. Further, Study 1 examined tension between one particular social concern that conflicts with financial motives in competitive negotiations—concern that maximizing earnings would undermine social rapport. But our proposed dual-hormone model should generalize to bargaining situations in which other social concerns conflict with maximizing earnings.

Study 2 investigated dual-hormone profiles in the ultimatum game, a controlled bargaining situation that directly pits financial motives against a different social motive—the desire to stand up to a perceived injustice (Güth, Schmittberger, & Schwarze, 1982). This bargaining game involves two players: a proposer and a responder. The proposer makes an offer as to how to split a sum of money (e.g., \$10) with the responder. The responder can accept or reject the offer. If the offer is accepted, the money is split as proposed. If the offer is rejected, then both players earn \$0. After the responder makes a decision, the game is over. A responder focused on maximizing financial earnings should accept any offer greater than \$0, because earning some money is better than none. Although responders almost always accept equal offers, many responders reject unequal offers (Güth et al., 1982). These unequal offers are often perceived as unfair and insulting, and a responder may reject these offers at a financial cost to punish the greedy proposer in the face of perceived provocation (Rilling & Sanfey, 2011). Thus, responder behavior can tease apart bargaining behavior that maximizes monetary rewards (accepting unfair offers) from financially costly bargaining behavior motivated by social concerns (rejecting unfair offers). If the profile of increased testosterone combined with increased cortisol is indeed related to social concerns that outweigh financial ones, then this dual-hormone profile should be associated with rejecting unfair offers. And if the profile of increased testosterone combined with decreased cortisol is implicated in maximizing monetary rewards, then this dual-hormone profile should be associated with accepting unfair offers. Study 2 tested these hypotheses.

## Method

**Participants.** One hundred fifteen participants (53% women, 47% men; ages = 18–30 years) participated in

exchange for payment based on their financial decision in the study. Participants were a mix of students and community participants in the greater Austin, Texas, area. A sample goal of at least 100 participants with approximately 50% women was determined in advance. College students were screened to ensure they had taken two or fewer courses in psychology or economics. Community participants were screened to ensure that they had not majored in psychology or economics. There were 108 participants with complete hormone and decision-making data.

**Procedure.** Participants completed online self-report measures prior to reporting to the lab. This survey included a trait aggression scale (Buss & Perry, 1992) as well as the Big Five personality inventory (John & Srivastava, 1999). After completing the online measures, participants reported to the lab between 10:30 a.m. and 5:30 p.m. and were escorted to private lab rooms adjacent to one another (see the Supplemental Material for limitations associated with variance in the time of day). Participants provided informed consent, filled out questionnaires relevant to hormone measurement, and then provided a 2-mL saliva sample (Schultheiss & Stanton, 2009).

The instructions for the ultimatum game told participants that they would be interacting with other participants in a computer-based economic game. A digital face photograph of each participant was taken against the same background (a white wall). Participants were told that the purpose of the photograph was so other participants in the study could see with whom they were interacting. Participants were told that they had been randomly assigned to the role of responder and would play the game in one-shot interactions with multiple proposers. Additionally, participants were informed that they would be paid 10% of their earnings in the game as a bonus payment. Participants were also told that they would play against a computer partner in some rounds and that the computer partner would randomly generate offers in these rounds. In reality, all offers were predetermined. Participants played 30 rounds of the ultimatum game in one-shot interactions (10 computer, 20 human proposers). Only photographs of individuals of the same sex as the participant were presented on trials with human partners. Photographs were pretested to be average in attractiveness. For computer rounds, a picture of a computer was shown. Each participant saw 12 fair offers (\$5:\$5) and 18 unfair offers (5 \$7:\$3 offers, 8 \$8:\$2 offers, and 5 \$9:\$1 offers) presented in random order. Participants indicated their decision to accept or reject offers by pressing "A" or "R" on their keyboard. The ultimatum game lasted approximately 10 min. We calculated the percentage of unfair offers accepted as our primary dependent measure.

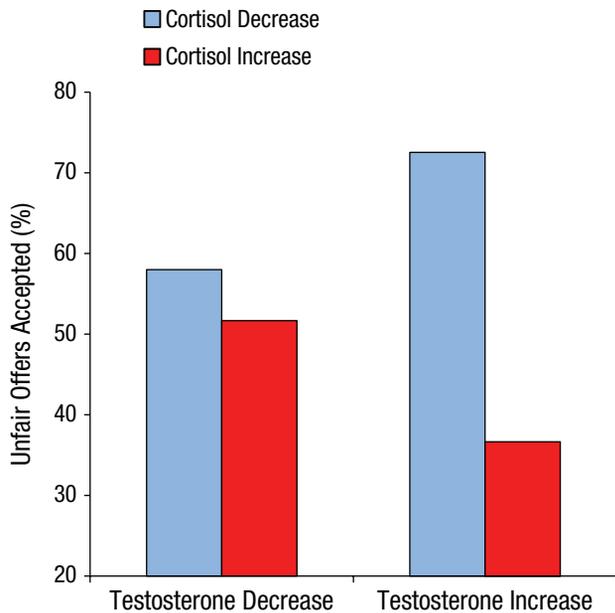
Immediately after the ultimatum game, participants filled out a short questionnaire in which they rated their agreement with four statements: "I enjoyed the game," "I am satisfied with how much money I earned in the game," "I want to play the game again," and "I am satisfied with how I played the game." All statements were rated on a 7-point scale from 1, *disagree strongly*, to 7, *agree strongly*. They also rated their state affect using the Positive and Negative Affect Schedule (Watson, Clark, & Tellegen, 1988). After participants had completed the questionnaire and approximately 20 min had elapsed, we asked participants to provide a second saliva sample to examine changes in hormone concentrations that occurred during the ultimatum game. This delay was used because prior research indicates that it takes approximately 20 min for hormone changes in response to a social interaction to peak (Denson, Mehta, & Ho Tan, 2013; Dickerson & Kemeny, 2004; Mehta & Josephs, 2010; see the Supplemental Material for additional discussion on the saliva-sampling strategy). Following the second saliva sample, participants filled out a questionnaire so we could check for suspicion in the study and were then paid and debriefed. (Additional supporting information about the Study 2 method, including a trial structure for the ultimatum game, can be found in the Supplemental Material.)

Saliva samples were shipped frozen overnight to Yerkes Endocrine Core Laboratory (Emory University, Atlanta, GA) and assayed for testosterone and cortisol using radioimmunoassay kits purchased from Diagnostic Systems Laboratories. Intra-assay variability for testosterone averaged 8%, and interassay variability averaged 11%. Intra-assay variability for cortisol averaged 6%, and interassay variability averaged 10%. Testosterone and cortisol levels before the ultimatum game were within normal ranges (testosterone in men:  $M = 140.61$  pg/mL,  $SD = 40.53$ ; testosterone in women:  $M = 27.27$  pg/mL,  $SD = 11.58$ ; cortisol in men:  $M = 0.23$  µg/dL,  $SD = 0.20$ ; cortisol in women:  $M = 0.20$  µg/dL,  $SD = 0.15$ ). Hormone-change scores from before to after the ultimatum game were slightly negative, which is consistent with circadian decline, but with substantial variance around the means (see the Supplemental Material).

In a postexperiment questionnaire, 7 participants expressed suspicion that they were not playing with real participants in the ultimatum game. We excluded these participants, which resulted in a total of 101 participants for our main analyses. Retaining suspicious participants resulted in very similar effects.

## Results

We conducted a hierarchical multiple regression analysis in which we regressed the percentage of unfair offers



**Fig. 5.** Percentage of unfair offers accepted in the ultimatum game as a function of whether testosterone and cortisol increased (1 *SD* above the mean) or decreased (1 *SD* below the mean) in Study 2.

accepted onto hormone-change variables. Changes in testosterone and cortisol were entered in Step 1, and the Testosterone Change  $\times$  Cortisol Change interaction was added in Step 2. Testosterone and cortisol changes were calculated by subtracting hormone concentrations before the game from concentrations after the game and then standardizing these scores. This analysis revealed a main effect of cortisol change in Step 1 ( $b = -7.71$ , 95% CI =  $[-13.545, -1.870]$ ),  $t(98) = -2.62$ ,  $p = .010$ . Conceptually replicating Study 1, this main effect was qualified by a Testosterone Change  $\times$  Cortisol Change interaction ( $\Delta R^2 = .048$ ;  $b = -7.46$ , 95% CI =  $[-13.922, -0.991]$ ),  $t(97) = -2.29$ ,  $p = .024$  (Fig. 5). In agreement with our dual-hormone model, results showed that the profile of increased testosterone combined with decreased cortisol was associated with decisions that led to monetary reward (accepting unfair offers), whereas the profile of both increased testosterone and increased cortisol was associated with decision making in which social concerns led to economic losses (rejecting unfair offers). Simple slopes analyses confirmed this interpretation. Cortisol change and acceptance of unfair offers were negatively related when testosterone increased ( $b = -18.31$ , 95% CI =  $[-29.14, -7.49]$ ),  $t(97) = -3.36$ ,  $p = .001$ , but were unrelated when testosterone decreased ( $b = -3.08$ , 95% CI =  $[-10.06, 3.90]$ ),  $t(97) = -0.88$ ,  $p = .38$ .

We next tested whether psychological traits that tap into social concerns relevant to the ultimatum game would predict the financially costly dual-hormone profile (increases in both testosterone and cortisol). Consistent

with our dual-hormone model, results showed that the financially costly dual-hormone profile was predicted by two self-reported traits that tap into the social motive to retaliate in response to a perceived injustice—low agreeableness: ( $b = -0.18$ , 95% CI =  $[-0.297, -0.061]$ ),  $t(98) = -3.01$ ,  $p = .003$ , and high aggression: ( $b = 0.17$ , 95% CI =  $[0.045, 0.294]$ ),  $t(96) = 2.71$ ,  $p = .008$  (see Figs. S2 and S3 in the Supplemental Material). Mediation analyses further demonstrated that the dual-hormone interaction statistically mediated the association between these psychological traits and ultimatum-game decisions (see the Supplemental Material for theoretical rationale and details related to these analyses).

Supplementary analyses also revealed that (a) dual-hormone interaction effects were corroborated when we used alternative-analysis approaches of hormone-change scores and when we included relevant control variables, (b) gender did not moderate these dual-hormone interaction effects, and (c) basal hormones were not significantly related to bargaining decisions (see the Supplemental Material).

## General Discussion

The present research identified a relation between dual-hormone changes and earnings in a face-to-face negotiation (Study 1) and a laboratory-based bargaining game (Study 2). An increase in testosterone combined with a decrease in cortisol was associated with strong earnings, whereas an increase in both testosterone and cortisol was associated with weak earnings. The findings suggest that when cortisol decreases, rising testosterone is related to behaviors that maximize monetary rewards. But when cortisol increases, rising testosterone is linked to bargaining behaviors in which social concern comes at a financial cost. Consistent with this explanation, Study 1 found that high concern over the negative social consequences of negotiating predicted the financially costly endocrine profile (increases in both testosterone and cortisol), whereas low concern predicted the financially adaptive endocrine profile (a testosterone increase and a cortisol decrease). Study 2 conceptually replicated these effects in a bargaining paradigm that pitted financial motives against a different social motive—the motive to retaliate in response to an economic insult. The profile of increased testosterone combined with decreased cortisol was associated with behavior that maximized monetary rewards, whereas the profile in which both testosterone and cortisol increased was related to financially costly bargaining behaviors that reflect social concern. Follow-up analyses revealed that dual-hormone changes also mapped onto relationship quality among negotiators. Together, these results break new ground in suggesting that (a) low versus high conflict between social

and financial concern in bargaining contexts relates to testosterone and cortisol fluctuations, and (b) these dual-hormone fluctuations are associated with objective financial performance and relationship quality.

Our results provide insights into the psychological mechanisms for dual-hormone interactions on bargaining outcomes—via conflict between social and financial concern—but complementary neural mechanisms may also be at play. One possibility is that the profile of increased testosterone combined with decreased cortisol may relate to reward-processing systems that are implicated in high earnings and positive social rapport (ventral striatum, ventromedial prefrontal cortex), whereas the profile in which testosterone and cortisol both increased may relate to social-threat-processing systems that are implicated in financially costly bargaining behaviors and acrimonious social interactions (amygdala and amygdala-prefrontal cortex connectivity; Denson, Ronay, von Hippel, & Schira, 2013; Gospic et al., 2011; Hermans et al., 2010; Hermans, Ramsey, & van Honk, 2008; Mehta & Beer, 2010; Sinclair, Purves-Tyson, Allen, & Weickert, 2014). Indeed, testosterone and cortisol relate to neural activity in these reward and social-threat regions, but a direct test of this mechanism requires further research. A related mechanism may be psychophysiological systems implicated in challenge versus threat (Kouzakova, Harinck, Ellemers, & Scheepers, 2014; O'Connor et al., 2010). A challenge state is activated when resources outweigh demands, whereas a threat state is activated when demands outweigh resources. Threat states may relate to the profile in which testosterone and cortisol both increase, and such states may stimulate behaviors that undermine earnings and relationship quality; in contrast, challenge states may relate to the profile in which testosterone increases and cortisol decreases, and such states may encourage behaviors that maximize earnings and relationship quality (see Denson, Mehta, & Ho Tan, 2013; Mehta & Josephs, 2010, for additional possible mechanisms).

We found associations between endogenous hormone changes and bargaining outcomes, but the causal pathways that explain these effects remain unclear. Mediation analyses provide initial support for a pathway from trait social concern to dual-hormone changes to earnings. This pathway from endocrine changes to earnings is consistent with nongenomic mechanisms, in which hormones exert rapid effects on the central nervous system within minutes or even seconds (Moore & Evans, 1999). Nevertheless, it is plausible that the mere act of achieving strong or poor earnings induced subsequent hormone changes in response to the bargaining interaction, presumably mediated by perceived satisfaction with earnings. Even though follow-up analyses failed to provide robust evidence for this reverse pathway (subjective

satisfaction with earnings was not a significant mediator of the pathway between earnings and dual-hormone changes; see the Supplemental Material), bidirectional pathways between hormone changes and earnings are still likely and may operate outside of conscious awareness. Bidirectional pathways are consistent with prevailing neuroendocrine theories, which posit that hormones and behavior influence each other dynamically in reciprocal feedback loops (Mazur & Booth, 1998). Future experimental research can build on our findings to address the onset, duration, and time course of reciprocal causation in bargaining contexts (further discussion of nongenomic mechanisms, additional theoretical implications, and limitations can be found in the Supplemental Material).

The present results also have implications for psychological interventions. Our theorizing and initial results suggest that interventions that reduce conflict between social and financial concerns may induce a profile of increased testosterone combined with decreased cortisol and improve bargaining outcomes, whereas interventions that heighten conflict between social and financial motives may increase testosterone and cortisol simultaneously and undermine bargaining outcomes. The present research represents an important first step, but future research can extend these results in order to develop evidence-based interventions. Ultimately, it is our hope that new hormonally informed interventions will help low-status individuals improve their bargaining outcomes and ascend social hierarchies.

### Author Contributions

P. H. Mehta designed the studies, analyzed the data, and wrote the first draft of the manuscript. S. Mor assisted with Study 1 design and execution and helped write the manuscript. S. Prasad and A. J. Yap assisted with data analysis and interpretation, provided suggestions, and helped write the manuscript.

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### Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

### Supplemental Material

Additional supporting information can be found at <http://pss.sagepub.com/content/by/supplemental-data>

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